IS 11349 (1985): Specification for Oscilloscopes and Peak Voltmeters for Impulse Tests [ETD 19: High Voltage Engineering]

BLANK PAGE

IS : 11349 - 1985
(Reaffirmed 2006)

Indian Standard

SPECIFICATION FOR OSCILLOSCOPES AND PEAK VOLTMETERS FOR IMPULSE TESTS

UDC 621·317·755 + 621·317·726 : 621·317·333·8

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 7 February 1986

Indian Standard

SPECIFICATION FOR OSCILLOSCOPES AND PEAK VOLTMETERS FOR IMPLUSE TESTS

High Voltage Techniques Sectional Committee, ETDC 19

Chairman	*Representing*
PROF B. I. GURURAJ	Indian Institute of Science, Bangalore
Members	
DR G. R. NAGABHUSHNA (*Alternate* to PROF B. I. GRURAJ)	
SHRI A. K. BARMAN	Calcutta Electric Supply Corporation Ltd, Calcutta
SHRI S. MUKHOPADHYAY (*Alternate*)	
DR S. C. BHATIA	Siemens India Ltd, Bombay
SHRI V. T. D'SILVA (*Alternate*)	
SHRI A. K. CHOPRA	Punjab State Electricity Board, Patiala
SHRI P. S. SATNAM (*Alternate*)	
CHIEF ENGINEER (TRANS PLG)	Maharashtra State Electricity Board, Bombay
SUPERINTENDING ENGINEER (PLG 400 KV LINES) (*Alternate*)	
SHRI V. B. DESAI	Jyoti Ltd, Vadodara
SHRI V. N. MALLER (*Alternate*)	
DIRECTOR	Central Power Research Institute, Bangalore
SENIOR DEPUTY DIRECTOR (*Alternate*)	
DIRECTOR (EHVD)	Central Electricity Authority, New Delhi
DEPUTY DIRECTOR (EHVD) (*Alternate*)	
SHRI P. K. DWIVEDI	National Thermal Power Corporation Ltd, New Delhi
SHRI N. V. RAO (*Alternate*)	
ENGINEER SUPERINTENDENT	U. P. Government Pottery Development Centre, Khurja
JOINT DIRECTOR STANDARDS (TI-1)	Research, Designs and Standards Organization Ministry of Railways, Lucknow
DEPUTY DIRECTOR STANDARDS (E) C_2 (*Alternate*)	
SHRI K. KASTURI	W. S. Insulators of India Ltd, Madras
SHRI S. RAJAN (*Alternate*)	
SHRI V. N. MANOHAR	Tata Hydro-Electric Power Supply Co Ltd, Bombay
SHRI G. K. VENKATA RAO (*Alternate*)	

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
Kumari Mary Mathew	Tamil Nadu Electricity Board, Madras
Shri V. Thulsiraman (*Alternate*)	
Shri S. K. Mukherjee	National Test House, Calcutta
Shri R. N. Mukherjee (*Alternate*)	
Shri V. H. Navkal	Bombay Electric Supply and Transport Undertaking, Bombay
Shri M. L. Dongre (*Alternate*)	
Shri S. D. Paliwal	Bharat Heavy Electrical Ltd, Hyderabad
Shri B. N. Ghosh (*Alternate* I)	
Shri K. Natarajan (*Alternate* II)	
Shri S. R. Potnis	Hindustan Brown Boveri Ltd, Bombay
Shri V. S. Mani (*Alternate*)	
Shri Mata Prasad	U. P. State Electricity Board, Lucknow
Shri S. C. Agarwal (*Alternate*)	
Dr K. V. N. Rao	Electrical Research and Development Association, Vadodara
Shri P. K. Joshi (*Alternate*)	
Shri R. Sriram	Karnataka Electricity Board, Bangalore
Shri H. H. Rayappa (*Alternate*)	
Shri C. R. Varier	Crompton Greaves Ltd, Bombay
Dr G. Parthasarathy (*Alternate*)	
Shri S. P. Sachdev, Director (Elec tech)	Director General, ISI (*Ex-officio Member*)

Secretary

Shri K. Ganesh
Deputy Director (Elec tech), ISI

Indian Standard

SPECIFICATION FOR OSCILLOSCOPES AND PEAK VOLTMETERS FOR IMPULSE TESTS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 22 July 1985, after the draft finalized by the High Voltage Techniques Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The object of this standard is:

a) to define the terms specifically related to the oscilloscopes and peak voltmeters used for impulse test,

b) to specify the necessary requirements for such instruments to ensure their compliance with the requirements for impulse tests, and

c) to indicate the tests and procedures which are necessary in order to fulfill these requirements.

0.3 Detailed guidelines on methods of high voltage testing are covered in IS : 2071. While IS : 2071 (Part 3)-1976* covers requirements for measuring accuracies of devices used in impulse tests, the present standard is envisaged to cover specific characteristics of oscilloscopes and peak voltmeters for impulse tests.

0.4 In the preparation of this standard considerable assistance had been derived from IEC Pub 790 (1984) 'Oscilloscopes and peak voltmeters for impulse tests' issued by the International Electrotechnical Commission.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

---

*Methods of high voltage testing: Part 3 Measuring devices (*first revision*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard applies to analogue oscilloscopes and to peak voltmeters used for measurements during tests with high impulse voltages and high impulse currents. It covers the specific characteristics and calibrations required to meet the measuring accuracies specified in IS: 2071 (Part 3)-1976*.

1.2 This standard does not cover general instrument requirements because they are dealt with in IS : 11018 (Part 1)-1984† and IS : 9176-1979‡.

SECTION 1 GENERAL

2. CONDITIONS OF USE

2.1 Range of Operating Conditions

2.1.1 The ranges of operating conditions given in Table 1 are those under which the instrument should operate satisfactorily and should meet the accuracy requirements when it has been calibrated.

Any exceptions to the values given in Table 1 shall be explicitly and clearly stated with an indication that they are exceptions.

TABLE 1 NORMAL OPERATING CONDITIONS FOR INSTRUMENTS WITH AC POWER SUPPLIES

Operating Conditions (1)		Range (2)
Environmental Conditions		
Ambient temperature		+5°C to +45°C
Ambient relative humidity		10 to 90 percent
Supply Conditions		
Mains supply voltage	Rated voltage	±10 percent rms ±12 percent ac peak
Mains supply frequency	Rated frequency	±5 percent

*Methods of high voltage testing: Part 3 Measuring devices (*first revision*).

†Method for expression of properties of cathode-ray oscilloscopes : Part 1 General.

‡Requirements for general purpose cathode-ray oscilloscopes.

2.1.2 If the instrument is operated under conditions different from those specified in Table 1, special precautions may be necessary.

The main supply may have transient overvoltages superimposed on it; suitable precautions should be taken to prevent these from affecting the operation of the instrument.

2.1.3 If the instrument is supplied by batteries:

a) it shall be capable of operating under the above environmental conditions;

b) the manufacturer should indicate the expected operating time at the reference temperature and also for the two ambient temperature extremes; and

c) the manufacturer should indicate the range of battery voltages over which the instrument will operate satisfactorily. It is useful to have a device which indicates when the battery voltage is too low.

2.2 Reference Conditions — The reference conditions are those for which the basic accuracy of the instrument shall be specified and under which investigation of the basic accuracy shall be made. These conditions are selected from IS : 6700-1972* and IS : 4330-1967† and are given in Table 2.

TABLE 2 REFERENCE CONDITIONS

CONDITIONS	REFERENCE VALUES	TOLERANCE ON REFERENCE VALUES
(1)	(2)	(3)
Ambient temperature	27°C	± 2°C
Ambient relative humidity	45% to 75%	
Supply voltage	Rated voltage	± 1 percent rms ± 2 percent peak
Supply frequency	Rated frequency	± 1 percent

NOTE — The specific temperature used as reference condition should be indicated. It is advisable to use the same temperature when checking the basic characteristics of the instrument.

*Requirements for general purpose cathode-ray oscilloscope.

†Methods of measurements on cathode-ray oscilloscope.

3. GENERAL DEFINITIONS

3.1 Transfer Characteristic — The transfer characteristic is the relationship between the input and the output quantities of the instrument expressed either as a function of frequency (frequency response) or time (step response). The transfer characteristic is usually presented in a normalized form by assigning the value of unity to the constant portion of the step or frequency response. The requirements on transfer characteristics include the effect of any built-in attenuator.

3.2 Scale Factor — The scale factor of the instrument is the factor by which the output indication is multiplied to determine the measured value of the input signal to the instrument. The scale factor includes the ratio of any built-in attenuator and is either indicated by the manufacturer or dertermined by appropriate calibration.

3.3 Deflection Coefficients — The deflection coefficient of the instrument is the ratio of the voltage (or time) interval to the corresponding deflection of the instrument. This coefficient refers mainly to oscilloscopes.

3.4 Nominal Values of the Deflection Coefficients — The nominal values of the deflection coefficients are those corresponding to a specific setting of the instrument and are either indicated by the manufacturer or determined by proper calibration.

If the instrument is linear the nominal values of the deflection coefficients are equal and constant over the entire scale or screen of the instrument.

If the nominal deflection coefficient is only constant over a limited part of the scale or screen, the instrument may still be considered linear provided the measurement is made within this linear portion.

3.5 Non-linearity — Non-linearity is any deviation of the actual deflection coefficient at any part on the scale or screen, from the nominal value for that part. It is usually expressed in the form of relative error defined as the ratio of the deviation to the nominal deflection coefficient. It does not include the effects of either ripple or limitation in the transfer characteristic of the instrument.

3.6 Instability — Instability is any variation of the characteristics of the instrument with time. It is usually expressed in the form of relative error defined as the ratio of the variation to the nominal value of the relevant quantity. It does not include the effect of change in the reference conditions.

3.7 Measuring Area or Scale — The measuring area or scale is the portion of the screen or of the scale within which measurements can be made with defined accuracy. It is indicated by the manufacturer or determined by calibration.

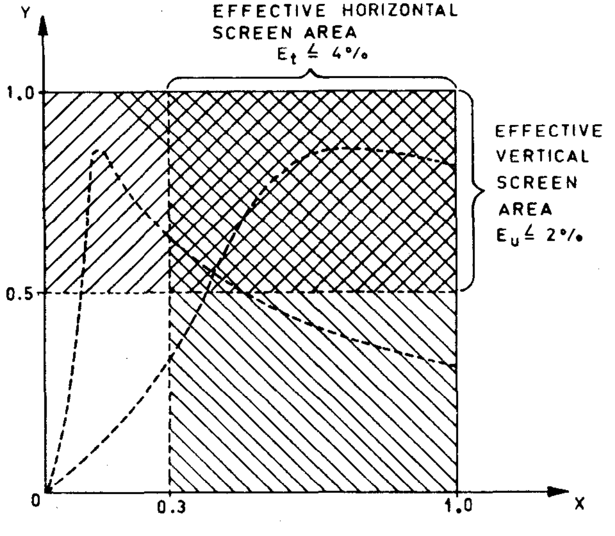
NOTE — The use of the word scale in this context applies to analogue and also digital type voltmeters.

3.8 Rated Deflection or Rated Scale — The rated deflection or rated scale is the maximum value within the limits of the measuring area or scale.

3.9 Effective Screen Areas or Effective Scale — The effective screen areas are those parts of the measuring area within which measurements can be made with the accuracies specified in **7.1**. An example of these effective screen areas for both vertical and horizontal deflections is shown in Fig. 1.

The effective scale is that part of the measuring scale where measurements can be made with the accuracy specified in **8.1**.

Measurements can be made outside the effective screen areas or scale but with lower accuracy.



E_t = Overall error in time measurement, and
E_u = Overall error in voltage (current) measurement.

FIG. 1 EFFECTIVE SCREEN AREA

3.10 Warm-Up Time — The warm-up time is measured under the reference conditions and is the time interval from when the instrument is first switched on, to when the instrument meets all the specifications.

NOTE — The time interval necessary to comply with all accruacy requirements may be considerbly extended under adverse operating conditions.

3.11 Absolute and Relative Error — The absolute error is the difference between the estimated or measured value and the true value. The relative error is the ratio of the absolute error to the true value and it is often expressed as a percentage.

3.12 Individual Error and Overall Error—The individual error is the error is the error of a specific measured quantity or of a specified parameter of characteristic of the instrument.

The overall error of the instrument is the combination of all its individual errors. In the case of digital peak voltmeters, it includes an additional error of ± 1 digit. This error does not include known corrections applied to the instrument reading to obtain the measured value.

The individual or overall errors may be expressed as absolute or relative values.

4. PERFORMANCE CHARACTERISTICS

4.0 The performance characteristics of the instrument are divided into two groups, the first is technical data supplied by the manufacturer or determined by the user through appropriate calibration, and the second is the characteristics checked and updated by the user in the performance tests.

4.1 These are periodic tests carried out to ensure that the instrument meets the specified requirements and that its characteristics have not changed significantly with time. The long term periodic tests are performed at regular intervals (for example, once a year), to check and update those characteristics listed under category A (*see* **8** and **12**). The short term periodic tests are checks performed regularly (if necessary, daily) to ensure that the instrument is functioning correctly (category B, *see* **8** and **12**).

After major repairs, more extensive tests are required to ensure satisfactory operation of the instrument and to update those characteristics affected.

4.2 Some recommendations on the test procedures are outlined in Appendices A and B.

4.3 The results of the test (except those of category B) should be recorded in the 'Record of Performance', which also includes the complete list of technical data, and is retained and maintained by the user.

5. INPUT CHARACTERISTICS

5.1 Instruments may include an internal attenuator to provide a stepwise division of voltage. In such a case, the requirements and definitions apply to the instrument including the attenuator.

The input impedance of an impulse measuring instrument should match the impedance of the coaxial cable when used with a resistive divider or shunt and should be as high as possible when used with capacitive or mixed dividers. It is therefore appropriate to construct the instrument with a high input impedance and to provide it with an internal or external adaptor to give the lower impedance when required.

5.2 Usually an input impedance equivalent to a resistance of not less than 1 MΩ in parallel with a capacitance of less than 50 pF is acceptable.

5.3 In the case of oscilloscopes it has to be varified that the change in scale factor of the entire measuring system, due to the input impedance of the instrument, does not exceed 5 percent at the greatest time to half value of the impulse to be measured. This may require an input impedance greater than 1 MΩ for impulses having a long time to half value.

NOTE — It should be verified that the input impedance of the instrument is not affected by the attenuator setting to such an extent as to upset the accuracy of the measurement.

SECTION 2 OSCILLOSCOPES FOR IMPULSE TESTS

6. GENERAL

6.0 The oscilloscopes used for impulse tests may be either impulse oscilloscopes specially designed for impulse measurements or general purpose oscilloscopes utilised with adequate precautions.

Impulse oscilloscopes are essentially well screened instruments with a high writing speed and a single sweep time base which can be triggered in synchronism with the impulse. Special impulse oscilloscopes have normally only passive elements between the input terminals and the deflection plates, but oscilloscopes using amplifiers may be used.

General purpose oscilloscopes including those equipped with probes are acceptable for recording impulse voltages (currents) provided that they comply with requirements given in this standard. In this standard no distinction is made between impulse and general purpose oscilloscopes. Some precautions to be taken are given in Appendix C. When an oscilloscope is equipped with a probe, this probe is considered to be part of the instrument.

Oscilloscopes have either internal calibration devices for the voltage deflection sensitivity and the sweep speed, or calibrated graticule or both. This calibration device may or may not include the calibration of built-in attenuators.

In the following it is assumed that the vertical deflection of the oscilloscope is used to record voltages or currents and the horizontal one is for the time sweep. Sometimes both the horizontal and vertical deflections are used to record voltages and currents. In such cases, the measuring accuracy of the horizontal deflection system may be lower than that of the vertical system.

When oscilloscopes are used in connection with peak voltmeters and are not intended to be applied for an accurate measurement of the voltage amplitude, then only the requirements on the accuracy of time measurements have to be fulfilled.

6.1 Writing Speed — The writing speed is the highest speed of the spot giving a visible trace on the recording under specified conditions of use. Recommendations on the selection of the writing speed according to the specific tests for which the instrument is used, are given in Appendix D.

6.2 Step Response and Rise Time — For oscilloscope it is normal practice to characterize the step response by the rise time t_r. The rise time t_r is the time interval within which the response to a rectangular pulse passes from 10 percent to 90 percent of its steady-state amplitude.

6.3 Oscilloscope Frequency Response — The frequency response is defined by the following parameters:

a) *Lower and upper cut-off frequencies* f_1 and f_2 — The lower and upper cut-off frequencies f_1 and f_2 are the frequencies at which the response to a constant sinusoidal input voltage has fallen by 3 dB (0·707) from the approximately constant level.

b) *Bandwidth* — The bandwidth is defined as the difference between the upper and lower cut off frequencies.

7. ACCURACY REQUIREMENTS

7.1 General — The overall error caused by the use of the oscilloscope should be not more than:

a) 2 percent in the peak voltage (current) measurement, and

b) 4 percent in the time measurement.

In order to stay within these limits, recommended limits for individual errors are given below. In some cases, one or more of these limits may be exceeded provided the permitted overall error is not exceeded.

In such cases, the overall error can be estimated from the individual errors by the statistical method given in IS : 8690-1977*.

7.2 Requirements on Transfer Characteristics — The rise time of the oscilloscope shall meet the following requirement:

$$t_r \leqslant \frac{1}{2\pi f_{max}}$$

where f_{max} is the highest oscillation frequency of significance that can appear at the test object, IS : 2071 (Part 3)-1976†.

Furthermore, t_r shall be not more than $0{\cdot}03T$, where T is the shortest time to chop which is expected to be measured [*see* IS : 2071 (Part 3)-1976]†.

The upper cutoff frequency (f_2) shall be higher than $2 f_{max}$, and the lower cutoff frequency (f_1) shall be lower than $0{\cdot}005/T_2$, where T_2 is the longest time to half value of the impulse to be measured.

NOTE — In some cases, the above requirements may not be sufficient to ensure that the step response of the oscilloscope is appropriate. In such a case, it is necessary to ascertain that the overshoot of the step response is lower than 10 percent and that the decay time is sufficiently long compared to the longest time to half value of the impulse to be measured.

7.3 Requirements on the Accuracy of the Calibration — Calibrators, whether internal or external, used in routine checks to determine the values of the deflection coefficients should have an error of not more than 0·5 percent of each displayed calibration signal.

More precise calibration, with an error as low as 0·1 percent, may be obtained by using calibrators in conjunction with high precision voltmeters.

7.4 Requirements on Linearity — The linearity error should be not more than 1 percent for the vertical (voltage) deflection and 2 percent for the horizontal time deflection, if only one value of the voltage or time deflection coefficients is given. If more than one calibration line or mark is used, in addition to the zero line, the linearity error may increase according to their number and location. Roughly, for equally spaced calibration lines or marks, the linearity error might be increased proportionally to the number of calibration lines or marks, without increasing the resulting measuring error, provided the measured deflection is included between two calibration lines or marks.

In the same manner, for the same linearity error, increasing the number of calibration lines or marks reduces the resulting measuring error.

*Application guide for measuring devices for high voltage testing.
†Methods of high voltage testing: Part 3 Measuring devices (*first revision*).

NOTE — Since geometric distortions contribute to the nonlinearity, they should be kept to a minimum.

7.5 Requirements on Stability — The variation of any deflection coefficient with time shall not exceed the limits given in Table 3.

TABLE 3 LIMITS OF STABILITY ERROR

(at constant operating conditions)

ITEM	OSCILLOSCOPES	
	With Calibration Device Used at Every Oscillogram, Percent	Without Calibration Device Used at Every Oscillogram, Percent
(1)	(2)	(3)
Vertical display		
Short term stability error	≤ 1	Not applicable
Long term stability error	Not applicable	≤ 1
Horizontal display		
Short term stability error	< 2	Not applicable
Long term stability error	Not applicable	< 2

If the calibration device is used for every impulse then any long term instability will be revealed by variation in the position of the calibration lines or time marks.

The requirement concerning short term stability has to be fulfilled for at least 30 minutes following the warm-up time interval. The requirement concerning long term stability has to be fulfilled in principle for 8 hours, but other times may be specified according to the time between calibration checks.

Since it largely depends on the type of construction and components used, the stability of the instrument, for the specified time, shall be guaranteed by the manufacturer.

NOTE — If the built-in attenuator is not included in the check made by the internal calibration device, then its long term stability shall cover a much longer period such as one year.

7.6 Requirements on Ripple — The variation of the deflection coefficient during any ripple cycle should be not more than 0·5 percent.

7.7 Requirements on the Accuracy of the Reading Process — The method of reading the Oscillogram should not produce in the final measurement an error or more than 1 percent of the rated deflection.

7.8 Limits on Interference — The maximun deflection from a reference line measured during an interference test, as described in Appendix B, shall be less than 1 percent of the expected deflection for the measurement. Greater values may be permitted if the interference does not affect the accuracy of the measurement.

8. RECORD OF PERFORMANCE

8.1 As far as applicable the list of technical data to be specified by the manufacturer or, if necessary, determined by the user through appropriate calibration, should conform to IS : 11018 (Part 1)-1984*.

Among others, this list should include the following quantities some of which are of special importance for the specific use of the instrument for impulse measurements:

a) Deflection coefficients,

b) Range of time sweeps,

c) Effective screen area,

d) Vertical deflection amplifier characteristics (if applicable),

e) Transfer characteristic,

f) Accuracy of calibrator (if applicable),

g) Stability of built-in attenuators (if applicable),

h) Stability of deflection coefficients,

j) Non-linearity of deflection coefficients,

k) Influence of ripple on deflection coefficients,

m) Sensitivity to interference, and

n) Value and duration of the maximum input voltage.

8.2 The following characteristics will be specifically checked in the performance tests (for the meaning of *A* and *B*, *see* **4**).

Long Term Periodic Tests (Category A)

A — Accuracy of calibrator

*Method of expression of properties of cathode-ray oscilloscopes : Part 1 General.

A — Effective screen area

A — Non-linearity (horizontal and vertical)

A — Transfer characteristic

Short - Time Tests (Category B)

B — Deflection coefficients

9. RECOMMENDED PROCEDURE FOR OSCILLOSCOPE MEASUREMENTS

9.1 A recommended procedure for obtaining accurate measurements is given below. It can be applied to the determination of the deflection coefficients in the daily check (category *B*, *see* **8**) or to the evaluation of each oscillogram recording in the case where the requirements on linearity are not strictly met.

NOTE — When more than one measurements are done on the oscilloscope during a day the check shall be made once during the day preferably before the first measurement.

Provided the requirements on stability are fulfilled, this procedure results in a degree of accuracy limited only by the precision with which the calibration voltages and times are known, and to which the corresponding deflections can be read.

9.2 The calibration oscillogram record should contain five traces, all obtained at the same time sweep, as shown in Fig. 2.

Trace 1 — The trace of the voltage, from which the input to the oscilloscope is to be determined.

Trace 2 — The trace of the time marks.

Trace 3 — The trace at zero input (the zero line).

Trace 4 — The trace showing the deflection D_l, measured from Trace 3, of an accurately known voltage U_l, D_l being smaller in magnitude than the peak deflection D_p on Trace 1.

Trace 5 — The trace showing the deflection D_h, measured from Trace 3, of an accurately known voltage U_h, D_h being larger than D_p.

NOTE — Traces 4 and 5 can be produced by internal or external calibrators.

The peak of the voltage to be measured is determined as:

$$U_p = U_l + \frac{U_h - U_l}{D_h - D_l} - (D_p - D_l)$$

If the instrument is essentially linear, either Trace 4 or Trace 5 can be omitted. In other cases D_l and D_h should be as close to D_p as necessary. When the requirement on the short term stability of the deflection coefficients is met, Traces 4 and 5 need to be included in only a few of the oscillogram records, taken at the beginning and at the end of each recording session, respectively. In the example the time to chopping of the impulse, is determined as:

$$T = T_1 + \frac{T_2 - T_1}{L_2 - L_1} (L - L_1)$$

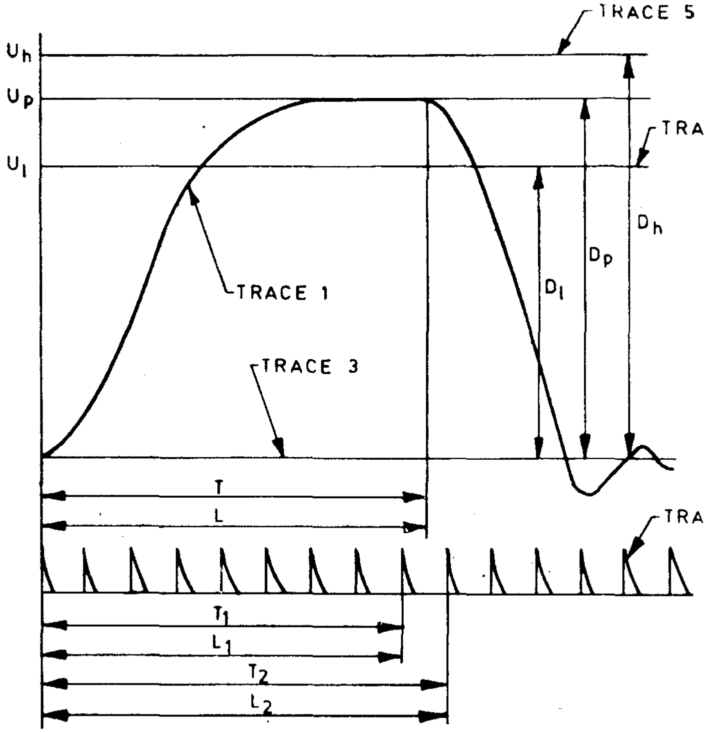


FIG. 2 EXAMPLE OF PROCEDURE FOR OSCILLOSCOPE MEASUREMENTS.

SECTION 3 PEAK VOLTMETERS FOR IMPULSE TESTS

10. GENERAL

10.0 Peak voltmeters used for impulse measurements may be either impulse peak voltmeters specially designed for impulse measurements or general purpose peak voltmeters utilized with adequate precautions. In this standard, no distinction is made between impulse and general purpose peak voltmeters.

10.1 A peak voltmeter measures the highest peak of the impulse. However, the highest peak of an impulse does not always comply with the value of the test voltage [*see* IS : 2071 (Part 2)-1974]*. This situation limits the use of the peak voltmeter by itself to those cases where the impulse shape is known to be quite smooth with no overshoot or oscillations at the peak. In all other cases, the peak voltmeter shall be used in parallel with a suitable recording instrument (usually an oscilloscope) so that the reading of the peak voltmeter can be corrected (if necessary).

The value may be displayed in either digital or analogue form.

10.2 If a peak voltmeter is used in connection with a probe, the probe is considered to be part of the instrument.

11. ACCURACY REQUIREMENTS

11.1 General — In order to meet the requirements on the overall error in voltage (current) measurement specified in IS : 2071 (Part 3)-1976†, the overall error of the peak voltmeter should not exceed 2 percent. In order to stay within these limits for all voltages equal to or greater than 0·5 times the rated scale voltage shall be of at least Class I accuracy.

Recommended limits for individual errors are given below. In some cases, one or more of these limits may be exceeded provided the permitted overall error is not exceeded. In such cases, the overall error can be estimated from the individual errors by the statistical method given in IS : 8690-1977‡.

11.2 Requirements on Transfer Characteristics — An indication of the transfer characteristics of the instrument can be obtained from the error encountered when measuring linearly rising impulses chopped on the front. The error of the peak voltmeter however cannot in general be evaluated in the same way as for oscilloscopes, that is by means of the step or frequency response. The error shall be determined experimentally with single impulses of different shapes covering the range of use of the instrument.

The manufacturer shall indicate the range of double exponential impules either full or chopped after the peak for which the error due to the transfer characteristics is not more than 1 percent. The range of front-

*Methods of high voltage testing: Part 2 Test procedures (*first revision*).

†Methods of high voltage testing: Part 3 Measuring devices (*first revision*).

‡Application guide for measuring devices for high voltage testing.

chopped impulses for which the error is not more than 3 percent shall also be indicated.

11.3 Requirements on Accuracy of the Calibrators — Internal calibrators and external calibrators used in routine checks, to determine the value of the scale factor shall have an error not exceeding 0·5 percent of each displayed calibration signal.

11.4 Requirements on Linearity — The linearity error shall be not more than 1 percent if only one calibration level, in addition to the zero level, is provided.

For more calibration levels the permissible linearity error may increase accordingly (*see* **7.4**).

11.5 Requirements on Stability — The variation of the scale factor with time between calibration checks shall be not more than 1 percent.

11.6 Requirements on Storage Time — According to the type of peak voltmeters, the indication may either be displayed until manual or automatic resetting, or decrease slowly after the impulse. In the latter case the manufacturer shall indicate the time for which the decay is not more than 1 percent.

11.7 Limits on Interference — The error in the measurement resulting from electromagnetic interference shall be small compared with the permitted overall error.

If the measurement is affected by the chopping of the impulse it shall be explicitly stated that the instrument may be used only for the measurements of full impulses.

Methods of testing immunity from interference are given in Appendix B.

12. RECORD OF PERFORMANCE

12.1 As far as applicable, the list of technical data to be specified by the manufacturer or if necessary, determined by the user through appropriate calibration should conform to IS : 11018 (Part 1)-1984*.

12.2 Among others this list should include the following quantities some of which are of special importance for the specific use of the instrument for impulse measurements:

a) Scale factor,

b) Usable scale,

*Method of expression of properties of cathode-ray oscilloscopes: Part 1 General.

c) Number of digits (if applicable),

d) Transfer characteristic,

e) Accuracy of calibrator (if applicable),

f) Stability of built-in attenuators (if applicable),

g) Stability of scale factors,

h) Non-linearity of scale factors,

j) Storage time (if applicable),

k) Sensitivity to interference, and

m) Value and duration of the maximum input voltage.

12.3 The following characteristics should be specifically checked in the performance tests (for the meaning of *A* and ***B***, *see* **4**).

Long Term-Periodic Tests (Catagory A)

A — Calibrator accuracy

A — Storage time (if applicable)

A — Non-linearity

A — Range of impulse shapes

Short Term Tests (Catagory B)

B — Scale factor

13. RECOMMENDATIONS FOR MEASUREMENTS WITH PEAK VOLTMETERS

13.1 In order to obtain accurate measurements with a peak voltmeter, the following recommendations should be followed:

The appropriate attenuator position should be selected in order to perform the measurement within the effective scale.

A calibration check should be made at a level as close as possible to the voltage to be measured.

13.2 If the voltmeter has a relatively short discharge time constant, then the reading should be noted in as short a time as posssible after the application of the impulse. Such time shall not exceed the maximum permissible time specified by the manufacturer.

APPENDIX A

(*Clause* 4.2)

PROCEDURE FOR PERFORMANCE TESTS

A-1. GENERAL

A-1.1 This appendix gives some guidance for the measurement of some characteristics of the instrument giving rise to individual errors, such as precision of the calibrators, deflection and transfer characteristics.

A-2. OSCILLOSCOPES

A-2.1 Calibrator Accuracy — Internal calibrators for voltage measurement are checked by comparison with a known accurate voltage. In some cases this is a dc voltage while in others it is a voltage having a square-wave shape

The calibrators for the horizontal deflection (time sweep) usually consist of time marks, sinusoidal oscillations or pulses of decaying oscillations. These can usually be checked by connecting either an accurate time mark generator or a sinusoidal voltage of known frequency or time marks displayed with those from the internal calibrator.

Checks of calibrator accuracies for both vertical and horizontal deflections are considered to be in category *A* (*see* **4**).

A-2.2 Deflection Characteristics — The method of determining the various deflection characteristics such as the deflection coefficients, non-linearity, etc, is based on applying known inputs to the instrument and measuring the resulting deflections.

To determine the vertical deflection characteristics, a series of accurately known voltages are applied and the resulting deflections measured. In addition to the zero line, the voltages should range from that level giving about 10 percent of the rated deflection to that giving 100 percent. The zero line should be made without time marks since the apparent zero of the time marks may be shifted from the true zero position. The number of levels required will depend on the degree of non-linearity of the deflection. For instruments which are essentially linear, eight to ten levels are sufficient but if the application of this number of levels indicates that the accuracy requirements of 7 are not met, additional levels will be required.

When the oscilloscope has a high input impedance, dc voltages may be used for the input, but for instruments with low impedance input, voltage pulses shall be used to prevent overloading the input circuitry. When voltage pulses are used, the pulse shall have a flat portion on top and the voltage level of this portion shall be accurately known. The flat portion of the pulse may extend over most of the screen width or only a small portion of it. In this latter case, provision should be made to shift the pulse laterally so that calibration can be made over the entire screen width to take into account geometrical distortions. This latter procedure is only necessary for an initial calibration or when the cathode-ray tube is replaced. Thereafter, one position of the pulse is usually sufficient. This technique is used to calibrate the graticule lines when a graticule is used or to check the calibration of an internal calibrator and determine the number of calibration levels required.

The above calibrations should be carried out with one setting of such instrument controls as intensity, astigmatism, focus, etc. Then for one particular deflection coefficient, the effect of changing these controls should be examined.

Many oscilloscopes have vertical deflection coefficients which are polarity sensitive or affected by the biasing of the plates. Consequently, appropriate measurement of the deflection characteristics should be made.

The method of determining the horizontal deflection characteristics is basically the same as for the vertical ones. However, in this case either a time mark generator or as high frequency oscillator is connected to the vertical deflection system and the time intervals along the horizontal axis measured. The time intervals should be sufficiently numerous to ensure that the accuracy specified in 7 is met as in the case of voltage levels for the vertical deflection. This calibration should be done on single sweep. If the test of the effect of intensity setting, astigmatism, focus, etc., on the vertical deflection characteristics indicate sensitivity to these settings, the specific settings of these controls should be recorded for each sweep time.

Where the above tests indicate that the deflection coefficients are within the permissible tolerances for only a portion of the screen, the nominal deflection coefficients for that portion are determined by averaging the actual deflection coefficients for that portion. The determination of the vertical and horizontal deflection characteristics are considered to be in category *B*.

A-2.3 Transfer Characteristics — One method of determining the transfer characteristics is to measure the step response of the instrument in the manner described in IS : 8690-1977*. However, for oscilloscopes the low voltage step generator is connected directly to the input terminals of the instrument or through a matching resistor to the input end of the measuring cable connected to the instrument. Since no modifications to the system

*Application guide for measuring devices for high voltage testing.

are required as in the case of complete measuring systems, the true step response of the instrument is obtained. The determination of the transfer characteristics is considered to be in category *A*.

A-2.4 Attenuators — The ratios of attenuators may be determined in the same manner as that used for determining the divider ratio (*see* IS : 8690-1977*). To check the transfer characteristics of an attenuator, the output is measured with a sensitive precision oscilloscope having a high input impedance when a low voltage step is applied to the input of the attenuator. The combined transfer characteristics of the oscilloscope plus attenuator must be within the limits given in **7**.

A-3. PEAK VOLTMETERS

A-3.1 Calibrator Accuracy — The calibration voltage is checked either by comparing it to an accurately known voltage or by measuring it with an accurate instrument of sufficiently high impedance so that the voltage is unchanged. Checks of calibrator accuracy are considered to be in category *A*.

A-3.2 Deflection Characteristics — The different characteristics, such as deflection coefficients or scale factors, usable scale, etc, are determined in a manner similar to that used for the vertical deflection system on an oscilloscope. The voltages used are impulse voltages of both polarities and of known amplitudes. The impulses should have a front time and a time to half value approximately in the middle of the ranges of the values for which the instrument is intended to be used (*see* 4).

A-3.3 Transfer Characteristics — Due to the operating principle of peak voltmeters, the transfer characteristics shall be determined by using the range of single impulse shapes of both polarities for which the instrument will be operated.

This determination may be performed at high voltage by simultaneous comparison with a measurement made with an oscilloscope which has been very accurately calibrated (the oscilloscope should have an upper cut-off frequency of at least 20 MH_z). If the determination is performed using low voltage impulses injected after the attenuator, the transfer characteristics of the attenuator shall be checked separately.

A-3.4 Attenuators — Attenuators for peak voltmeters may be checked in a manner similar to that described for those of oscilloscopes.

*Application guide for measuring devices for high voltage testing.

APPENDIX B

(*Clauses* 4.2, 7.8 *and* 11.7)

INTERFERENCE TESTS

B-1. GENERAL

B-1.1 The interference test is made in order to prove that the instrument has a sufficiently low sensitivity to interference, defined here as the deflection caused by any signal entering the instrument by any path, except *via* the measurement terminals. This property also concerns any undesired coupling between circuits within the instrument itself.

The interference affecting the measuring instrument may take different forms which, for the purpose of this document, can be grouped in the following main categories:

a) *Currents reaching the case of the instrument through the shield of the measuring cable* — Depending on the effectiveness of the shielding of the instrument these currents may or may not penetrate into the active parts of the instrument, giving rise to erratic deflections. Note that they also produce a measuring error caused by a potential difference appearing across the cable terminals at the instrument side (*see also* Appendix C).

b) *Currents reaching the case of the instrument through the shield of control cables* (*such as triggering cables*) — They may penetrate into the active parts of the instrument in a similar manner as for the measuring cable.

c) *Transients superimposed on the power frequency in the mains wires* — These transients may or may not affect the active parts of the instrument depending on the effectiveness of the isolating transformer and filtering devices.

d) *Electric and magnetic fields directly penetrating, through the cabinet, into the active parts of the instrument*

Furthermore (in the case of oscilloscopes) interference may also be produced by parasitic coupling between the internal circuits and the signal injected *via* the external triggering terminals, especially when an antenna is used for external triggering. In double beam oscilloscopes, coupling between the two beams may also produce interference.

B-2. INTERFERENCE CHECK

B-2.1 This test is made in order to check the overall sensitivity to interference of the measuring instrument in a given measuring circuit and for given operating conditions.

During the test the measuring layout (earthing, routing of measuring cable, control, cables and power cables) and the high voltage circuit (position of the impulse generator, front capacitor, chopping devices, voltage divider) shall be as close as possible to that used for the measurement. The measuring cable shall be short-circuited (or terminated by its surge impedance) at the divider end and earthed in the same way as for the normal measurement. To avoid incorrect interpretation in the case of oscilloscopes, care should be taken that the triggering takes place at the right instant.

The impulse generator shall be charged to the relevant operating voltage and fired. The test could be performed with full impulses if the system is not intended to be used for chopped wave tests. Otherwise, the test shall be performed by chopping the impulse in the vicinity of the crest by an adequate chopping device. In this case the voltage amplitude may be reduced if necessary with respect to the maximum test voltage to avoid overstressing the test object if in the circuit.

NOTE 1 — An adequate chopping device is the breakdown of an air gap with essentially homogenous field, such as a sphere-sphere gap or a multiple chopping gap. For special cases, however, the chopping of such a device may not be fast enough and other devices, such as compressed gas gaps, may be required.

NOTE 2 — For peak voltmeters the chopping of the impulse shall be between 1 and 3 μs after the peak of the voltage. The peak voltmeter should exhibit the same reading with and without chopping.

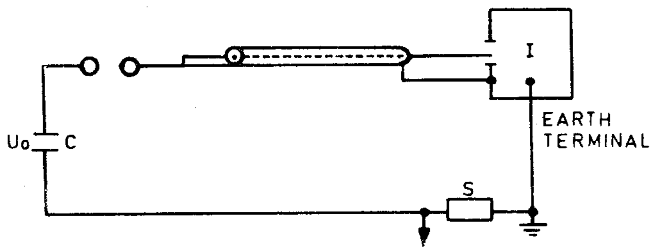
NOTE 3 — In the case of oscilloscopes, this test may not show interference on the time base. To investigate this type of the interference, the measuring cable should be disconnected from the oscilloscope, leaving, however, the shield of the cable connected to the instrument case, and a separate sinusoidal voltage of suitable amplitude shall be applied to the oscilloscope. In the same test conditions as above, the recorded sinusoidal oscillation should exhibit negligible distortion.

B-3. INDIVIDUAL INTERFERENCE TESTS

B-3.0 These tests are made in order to check the sensitivity of the instrument to each of the different types of interferences listed above. The tests are basically intended for the manufacturer of the instrument, but they could also be useful for the user, to ascertain which type of interference is most critical for an instrument that failed during the complete interference test.

NOTE — Passing the individual interference tests will not necessarily guarantee that the instrument will operate satisfactorily in the actual test arrangement. However, failing the individual test will be a clear indication of the inadequacy of the instrument.

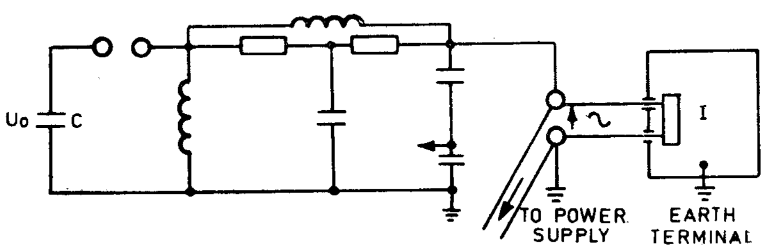
B-3.1 Current Injection into the Shield of the Cables — This test applies to both measuring and control cables (if any). The cables shall be connected to the instrument in the same way as for the normal operation. The current to be injected in the shield of the cable should preferably consist of a main oscillation having an amplitude of 100 A and a frequency of 1 to 2 MHz, and of a superimposed oscillation of amplitude 10 A and frequency 10 to 20 MHz. A possible test circuit is shown in Fig. 3.



S = current measuring shunt, and
U_0 = charging voltage.

FIG. 3 CURRENT INJECTION INTO THE SHIELD OF THE CABLE

B-3.2 Transients Superimposed on the Power Supply — This transient should preferably consist of an initial fast rise pulse (rise time not more than 100 ns), followed by a damped oscillation of frequency not less than 100 kHz superimposed on the main supply voltage, with an open-circuit charging voltage of not less than 5 kV and a short-circuit current of not less than 200 A. A possible test circiut is shown in Fig. 4.

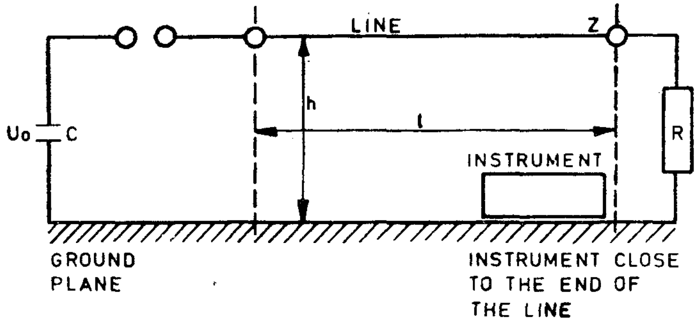


U_0 = charging voltage.

FIG. 4 TRANSIENT SUPERIMPOSED ON THE POWER SUPPLY

B-3.3 Application of Electric and Magnetic Fields — The instrument, including any additional shielding added to it, shall be submitted to rapidly changing electric and magnetic fields of approximately 10 kV/m and 1 000 A/m respectively.

These fields may be obtained by the discharge of a capacitor *via* an open air sphere gap as shown in Fig. 5.



Z = characteristic impedance,
C = 20 nF,
l = 5 m, and
h = 1 m.
For the electric field test U_0 = 40 kV (R = Z)
For the magnetic field test U_0 = 100 kV (R = O)

Fig. 5 APPLICATION OF ELECTRIC AND MAGNETIC FIELDS

For tests with electric field, the line connected to the capacitor, shall be terminated by its surge impedance ($R = Z$).

For test with magnetic fields the line connected to the capacitor shall be short circuited (R = O).

The corresponding transient characteristics are determined by the parameters of that test circuit and are : for the voltage, a step with a rise time of about 50 ns and for the current, a damped oscillation with a frequency of about 0·5 MHz.

The test is not applicable if the instrument is operated in a well shielded areas.

B-3.4 Additional Tests for Oscilloscopes

B-3.4.1 For oscilloscopes triggered externally *via* an antenna, an additional interference test should be carried out using a time sweep of about 10 μs.

The high voltage test circuit should be the same as when making measurements and should include a shpere gap set to spark over at or near the peak of the impulse. The measuring cable should be disconnected from the oscilloscopes and short-circuited but the sheath of the cable may be connected to the case of the instrument. The input to the measuring terminals of the oscilloscope should be a sinusoidal voltage having a frequency of the order of 1 to 5 MHz and its amplitude should be such as to produce a vertical deflection of the order of 5 to 10 percent of full scale. The impulse generator is charged to the maximum voltage and fired and the recorded sinusoidal oscillation should exhibit negligible distortion.

B-3.4.2 For double beam oscilloscopes the full deflection shall be produced on one beam, checking that no erratic deflection is induced on the other beam.

B-4. EVALUATION OF INTERFERENCE TESTS

B-4.1 For all the tests listed above, the test is considered satisfactory if the parasitic deflection produced on the instrument is within the limits given in **7.8** or **11.7**.

APPENDIX C

(*Clause* 6.0)

PRECAUTIONS IN THE USE OF GENERAL PURPOSE INSTRUMENTS

C-1. GENERAL

C-1.1 General purpose instruments usually suffer from two major disadvantages. Their sheilding is normally not adequate for use in a high voltage laboratory and the accuracy of built-in calibrators is not sufficient for the measuring accuracy required.

In the case of internal calibrators, their accuracy should be checked and, if necessary, external calibrators of adequate precision used instead.

C-2. OSCILLOSCOPES

C-2.1 General purpose oscilloscopes shall be capable of operating in the single sweep mode for use in recording impulses. A lockout feature may be required to prevent multiple triggering due to interference. The accuracy being often outside of the requirements of 7, additional calibrations may be needed.

Interferences are generally excessive on both the vertical and horizontal axis, especially in the case of chopped impulses. The following precautions may reduce the interferences to an acceptable level:

a) Interferences due to electromagnetic field directly penetrating into the instrument may be reduced by placing the entire instrument into an auxiliary metal enclosure having bonded joints, and made of suitable materials such as aluminium or copper. It is important to ensure that the ventilation of the instrument is not impaired when this technique is used and ventilation openings covered with copper or aluminium mesh should be incorporated.

b) Interferences due to current flowing in the shield of the measuring cable may be reduced by an adequate earthing at the voltage divider side, be using double coaxial cable with the outer shield grounded at both divider and instrument ends (or cables running into metallic conduits connected at both ends to the local grounds), and by avoiding loops between the measuring cable and the earth returns.

c) Interferences due to potential differences induced or applied between the terminals of the measuring cable may be reduced by using an input voltage as high as possible, and namely by operating the instrument on its maximum deflection coefficient range, or by inserting an external attenuator between the cable and instrument. Also the use of double shielded cables or cables placed in metallic conduits [*see* (b) above] will be effective in limiting the potential difference appearing between the cable terminals.

d) Interferences coming from the mains supply can usually be reduced by inserting an isolating transformer with low interwinding capacitance between the instrument and the mains supply. It may be useful to add, between the isolating transformer and the mains, a high frequency filter in order to provide a high series impedance between the mains and the isolating transformer and a low parallel impedance between the mains terminals and ground, so that the interferences coming from the mains are further shunted to earth.

   Note that the isolating transformer and the filter mentioned above may also act in the sense of limiting the currents flowing from the measuring system, through the cable shield and the instrument internal grounds, to the power line ground.

C-3. PEAK VOLTMETERS

C-3.1 These instruments are in general subjected to the same type of interference as oscilloscopes, being even more sensitive. Similar approaches to those outlined above should be taken.

NOTE — Unlike oscilloscope, it is impossible to tell from the instrument reading if the interference affects the measurement. Consequently, it is of extreme importance that interference effects be minimized.

APPENDIX D

(*Clause* 6.1)

SPECIAL RECOMMENDATIONS FOR OSCILLOSCOPES

D-1. TIME SWEEP AND WRITING SPEED

D-1.1 In principle, the necessary range of sweep times is determined by the shape of the voltages to be recorded (type of tests). An indication of the full deflection times recommended for various standardized tests is given in Table 4.

An adequate sequence of time sweep settings should be provided with a ratio of scaling of 1, 2, 5, 10, etc, and the range of 0.5 μs to 50 ms.

NOTE — The overall range of time sweeps may not be available on the same instrument and consequently two instruments may be required for some tests.

The necessary writing speed is determined by the highest deflection steepness to be recorded and by the fastest time sweep to be used. The obtainable writing speed depends on the characteristics of the oscilloscope (accelerating voltage and type of phosphor) and on the recording system used (type of camera, object to image ratio, film material, film processing).

The values of writing speed thus refer to the combined set of oscilloscope plus camera system. The latter should always be specified when indicating a value of writing speed.

D-1.2 Table 4 gives recommended values of the writing speed for the various standardized tests considered, with reference to a 'normal' size of the recorded oscillogram, namely 6 cm × 10 cm. If the recording has a smaller size, then the required values of writing speed may be reduced proportionally to the reduced dimensions.

The values of Table 4 are an estimate of the minimum values required to ensure that the considered impulse shapes are properly recorded on the oscillogram. Higher values may be required for the measurement of the step response of the oscilloscope, unless a repetitive step generator is used.

NOTE—Besides the normal linear deflection, a deflection permitting an expansion of the time of recording (logarithmic or zigzag) may be useful.

TABLE 4 RECOMMENDED RANGES OF RATED SWEEP TIMES AND MINIMUM WRITING SPEED, FOR VARIOUS STANDARDIZED IMPULSE TEST AND MEASUREMENTS

(*Clause* **D-1.1,** *and* **D-1.2**)

TESTS	RATED SWEEP TIMES		MINIMUM WRITING SPEED
	From	To	cm/μs
(1)	(2)	(3)	(4)
Determination of the response time by the sphere gap method Impulse chopped on front; T_c between 0·4 and 1 μs	0.5 μs	5 μs	200
Standard lightning impulses 1·2/50 μs full or chopped on the tail	1 μs	200 μs	50
Standard impulse currents 4/10 and 8/20 μs	1 μs	200 μs	50
Standard switching impulses 250/2500 μs	50 μs	5 ms	10
Line discharge currents	50 μs	5 ms	10
Phase-to-phase switching impulses			
Switching impulse — AC combined tests	200 μs	50 ms	10
Lightning impulse — AC combined tests	1 μs	50 ms	50
Duty cycle tests of surge arresters	1 μs	50 ms	50

D-2. ATTENUATOR STEPS

D-2.1 The selection of the attenuator steps should also take into account the necessity of obtaining similar deflections with impulses of different peak value, in tests consisting of the application of a series of such impulses.

The following table lists a sequence of attenuator settings which has proved to be practical:

	Steps										
Attenuator	1	1·25	1·6	2	2·5	3·2	4	5	6·4	8·0	10·0

D-3. EFFECTIVE SCREEN AREAS

D-3.1 The effective screen areas depend essentially on the individual errors and on the method of calibration (number and position of calibration levels).

Assuming that all the individual errors are in accordance with the values listed in **7** and considering for the sake of the example only tone calibration level in addition to the zero line, the following ranges are obtained:

Vertical axis : for a calibration level in the vicinity of the centre of the rated deflection, the effective area is restricted to the part between 0·50 and 1 times the rated deflection.

Horizontal axis : for a time mark in the vicinity of 0·5 of the rated time sweep, the effective area of the screen is restricted to the part between 0·3 and 1 times the rated time sweep time.

Figure 1 shows the effective screen areas (shaded parts), namely, the areas in which the errors in voltage and time measurements are within the limits specified in **7.1**. Measurements can be made outside the effective screen areas but with lower accuracy.

If more than one calibration level is provided for both deflections, larger individual errors may be accepted for the same effective screen area.

In a similar manner, for the same individual errors, the effective screen areas may be increased. However to significantly expand the effective area below 0·5 for the vartical axis and below 0·3 for the horizontal axis the reading error shall be reduced with respect to the value specified in **7.7**.

D-4. DOUBLE TIME BASE

D-4.1 If double beam oscilloscopes are equipped with two time bases. It may be desirable to operate both traces from a single time base, to eliminate time shifts between the two bases.

D-5. THICKNESS OF THE RECORDED TRACE

D-5.1 For all the specified conditions of use the thickness of the recorded trace should be not more than 2 percent of the rated deflection.